

Don't Feed the Bugzilla: Squash (Heisen)bugs Before Release

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Wake-up call... *it's only 10:30am*

Quiz: Find the **5** issues in below pseudo-C code?

Thread 0

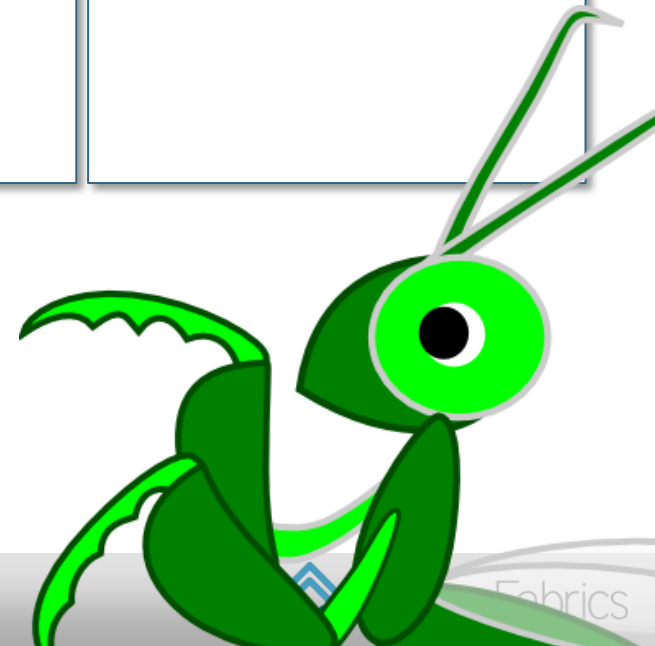
```
t1 = t2 = sum = 0;  
spawn Thread 1;  
spawn Thread 2;  
while (!t1 && !t2)  
    /* nothing */ ;  
print sum;
```

Thread 1

```
repeat 100:  
    sum++;  
t1 = 1;
```

Thread 2

```
repeat 100:  
    sum++;  
t2 = 1;
```



Woken up? The answers!

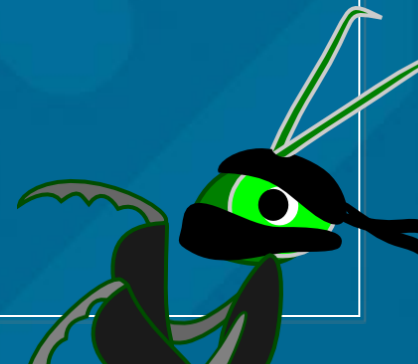
1. BUG: `&&` should be `||`
2. `sum++` translates to load-inc-store
 - not thread-safe and constitutes a data race.
3. Loads/stores of `t1` and `t2` can be optimized away by the compiler (to processor registers).
 - The `while` will hang and print nothing at all.
 - The `while` may be optimized away as well
 - `volatile` can address the hang but not many other issues.
4. A non-sequential memory consistency model of the processor can break the 'barrier' based on `while`.
5. Code likely to run slower than sequential version
 - amount of overhead versus little workload (200 increments).

Outline

- **What's a Heisenbug?**
- **How do you find (Heisen)bugs?**
- **When/Where do you find bugs?**
- **Summary**

Throughout the presentation, we will show examples of bugs found in open source projects

What is a Heisenbug?



What's a “Heisenbug”?

In computer programming jargon, a **Heisenbug** is a software bug that seems to disappear or alter its behavior when one attempts to study it.

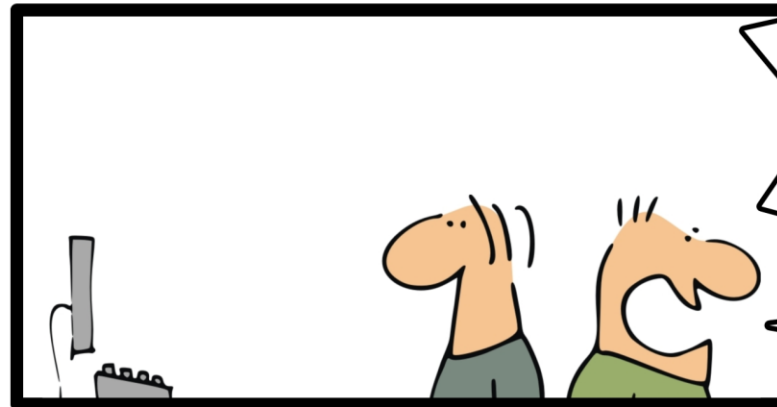
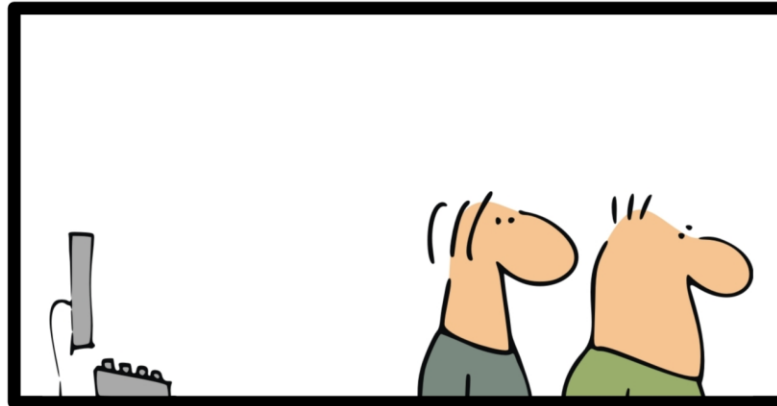
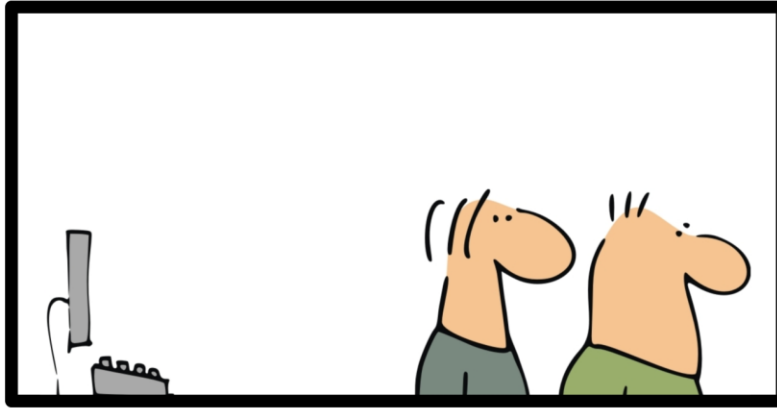
The term is a pun on the name of Werner Heisenberg, the physicist who first asserted the **observer effect** of quantum mechanics, which states that *the act of observing a system inevitably alters its state*.



WIKIPEDIA
The Free Encyclopedia

THE ART OF BUGFIXING

geek & poke



DON'T LOOK
AT THE
SCREEN!!!!

HOW TO DEBUG HEISENBUGS

~~printf~~

~~gdb~~



Heisenbugs: Typology

General problems:

- Timing Issues
- Use of Stale Data
- Use of Random Data

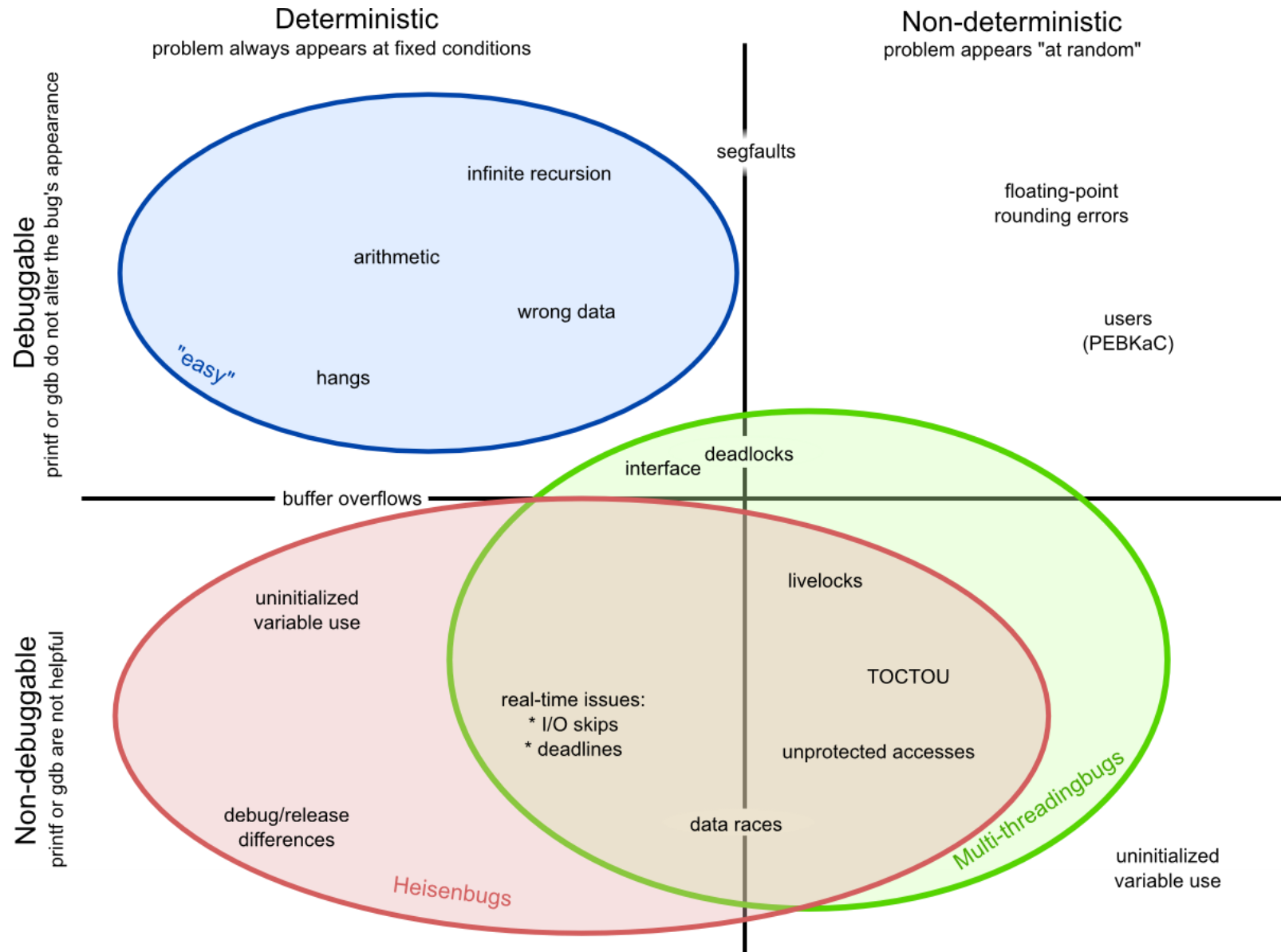
Usually “reproducible”

Not “debuggable”

Causes:

- Use of Uninitialized Data
- Buffer Overflows
- Use after Free
- Data Races
- Memory Ordering issues
- Debug-Release Differences
- TOCTOU

Bug categories



Navigation software

Features:

- Map display in 2D
- Route planning
- Route guidance
- Speech instructions

High quality code:

- Open source: peer reviewed
- Code quality confirmed by **Coverity** (static analysis)

<http://sourceforge.net/projects/navit/>

EXAMPLE



NAVIT

1) Read from uninitialized stack object

```
void
tracking_update(struct tracking *tr, struct vehicle *v, struct vehicleprofile *vehicleprofile, enum
projection pro)
{
    ...
    struct coord cin;
    ...
    transform_distance_line_sq(&sd->c[i], &sd->c[i+1], &cin, &lpnt_tmp),
    ...
}

int transform_distance_line_sq(struct coord *l0, struct coord *l1, struct coord *ref, struct coord *lpnt)
{
    ...
    wx=ref->x-l0->x;
    wy=ref->y-l0->y;
    if (transform_overflow_possible_if_squared(4, vx, vy, wx, wy)) {
        return INT_MAX;
    }

    c1=vx*wx+vy*wy;
    if ( c1 <= 0 ) {
        if (lpnt)
            *lpnt=l0;
        return transform_distance_sq(l0, ref);
    }
}
```

Stack object is NOT set to zero

'cin' passed as 'ref'

Memory read here

Decision here

Side effects

2) Use after deallocation

`binmap_search_new()` , `navit/map/binfile/binfile.c` 2128-2140

```
...
map_rec = map_rect_new_binfile(map, NULL);
town = map_rect_get_item_byid_binfile(map_rec, map->last_searched_town_id_hi,
                                       map->last_searched_town_id_lo);
...
map_rect_destroy_binfile(map_rec);
if (msp->boundaries)
    dbg(lvl_debug, "using map town boundaries\n");

if (!msp->boundaries && town)
{
    binmap_get_estimated_boundaries(town, &msp->boundaries);
    if (msp->boundaries)
        dbg(lvl_debug, "using estimated boundaries\n");
}
```

map_rec allocated

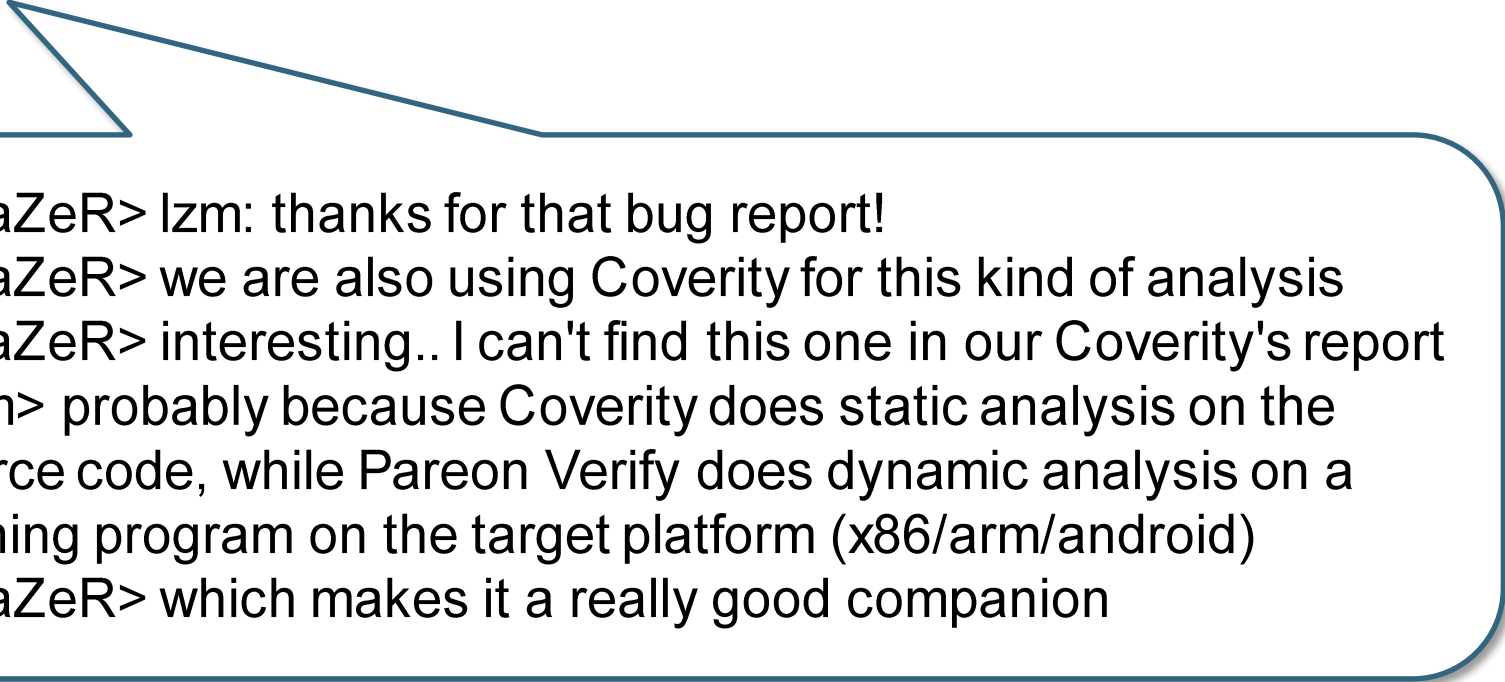
town is ptr to field inside map_rec

**map_rec freed,
town now points to unallocated**

town used again

Dynamic Analysis is a good companion

We (Izm) filed a bug: <http://trac.navit-project.org/ticket/1316>
NAVIT developer (KaZeR) on IRC #navit; Aug 26 2015:



< KaZeR> Izm: thanks for that bug report!
< KaZeR> we are also using Coverity for this kind of analysis
< KaZeR> interesting.. I can't find this one in our Coverity's report
<Izm> probably because Coverity does static analysis on the source code, while Pareon Verify does dynamic analysis on a running program on the target platform (x86/arm/android)
< KaZeR> which makes it a really good companion

Bug was fixed day after reporting

A photograph of a railway track. In the foreground, a large, weathered metal pole stands next to the tracks. The tracks are made of steel rails on concrete sleepers, with gravel ballast. To the left of the tracks is a dirt and gravel area. In the background, several large, cylindrical oil tankers are parked on the tracks. The sky is blue with some clouds.

How do you find (Heisen)bugs?

How to find Heisenbugs?

Heisenbugs are “non-debuggable”:

- Direct observation doesn't work

~~printf
gdb~~

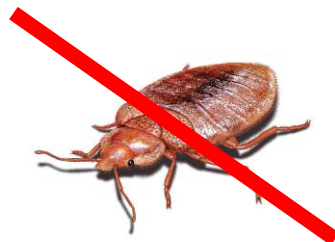
Solution: use ‘non-invasive’ tools:

- **Static analysis:**

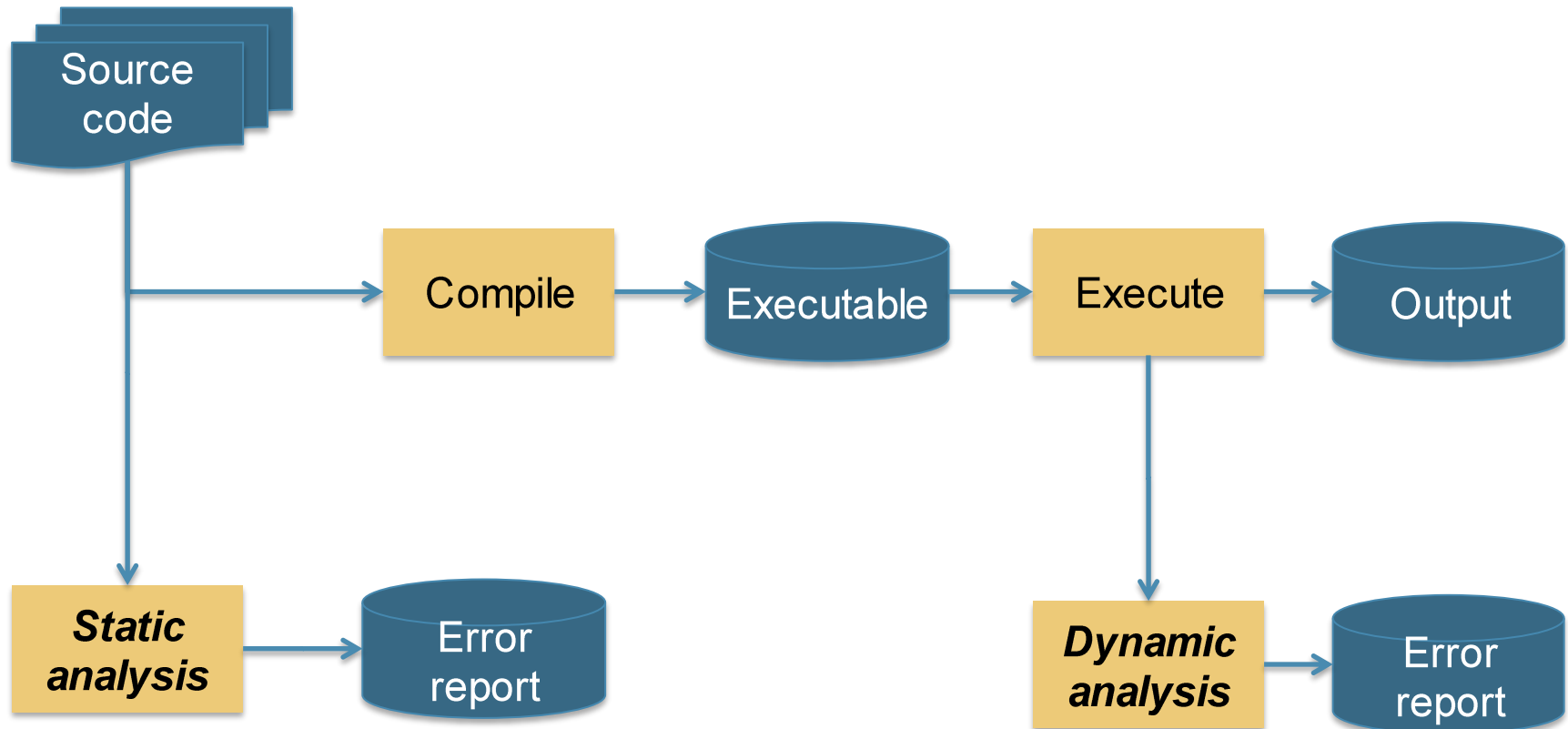
- Compile time: parse code and understand flow
- Examples: cppcheck, pclint, Coverity, Klockwork, CodeSonar, QAC

- **Dynamic analysis:**

- During execution, analyze (instrumented) binary
- Examples: Valgrind/Memcheck/Helgrind, TSAN/MSAN/ASAN, Vector Fabrics' **Pareon Verify**



Static Analysis vs Dynamic Analysis



“JMDecode” H.264 reference software

EXAMPLE

- H.264 - video coding standard
- Golden reference implementation maintained by Fraunhofer
- Mature open-source project
- 117K lines of C
- <http://iphome.hhi.de/suehring/tml>



H.264 reference software

```
char INIT_FLD_MAP_I[1][8][15][2];  
...  
IBIARI_CTX_INIT2 (NUM_BLOCK_TYPES, NUM_MAP_CTX,  
... tc>map_contexts[1], INIT_FLD_MAP, model_number, qp);  
...  
int pstate = ((ini[0]* qp )>>4) + ini[1];
```

value 22, in macro mapped to 2nd index

- Multi-dimensional array
 - accessed inside its boundaries
 - with a wrong index
 - getting wrong data via a pointer
 - from a valid data element
- Test case succeeds!

Pareon Verify error message

```
[M0193] Static-buffer overflow(s) detected:
the read in
  function biari_init_context at biaridecod.c:299
  called from function init_contexts at context_ini.c:90
  called from function decode_one_frame image.c:943
  called from function DecodeOneFrame at ldecod.c:1254
  called from function main at decoder_test.c:245
performed 210 access of size 1 between the offsets of 240 and 658 bytes of
the object of size 240 allocated as `INIT_FLD_MAP_I' at ctx_tables.h:879
where array index 21 is outside of array `INIT_FLD_MAP_I[][0..7][[]]' in
  function init_contexts at context_ini.c:90
  called from function decode_one_frame at image.c:943
  called from function DecodeOneFrame at ldecod.c:1254
  called from function main at decoder_test.c:245
```

- Exact specification of the faulty index in the array
- Bug fixed two days after the submission
- <https://ipbt.hhi.fraunhofer.de/mantis/view.php?id=348>

Where/When to find bugs?



Where do you find bugs?

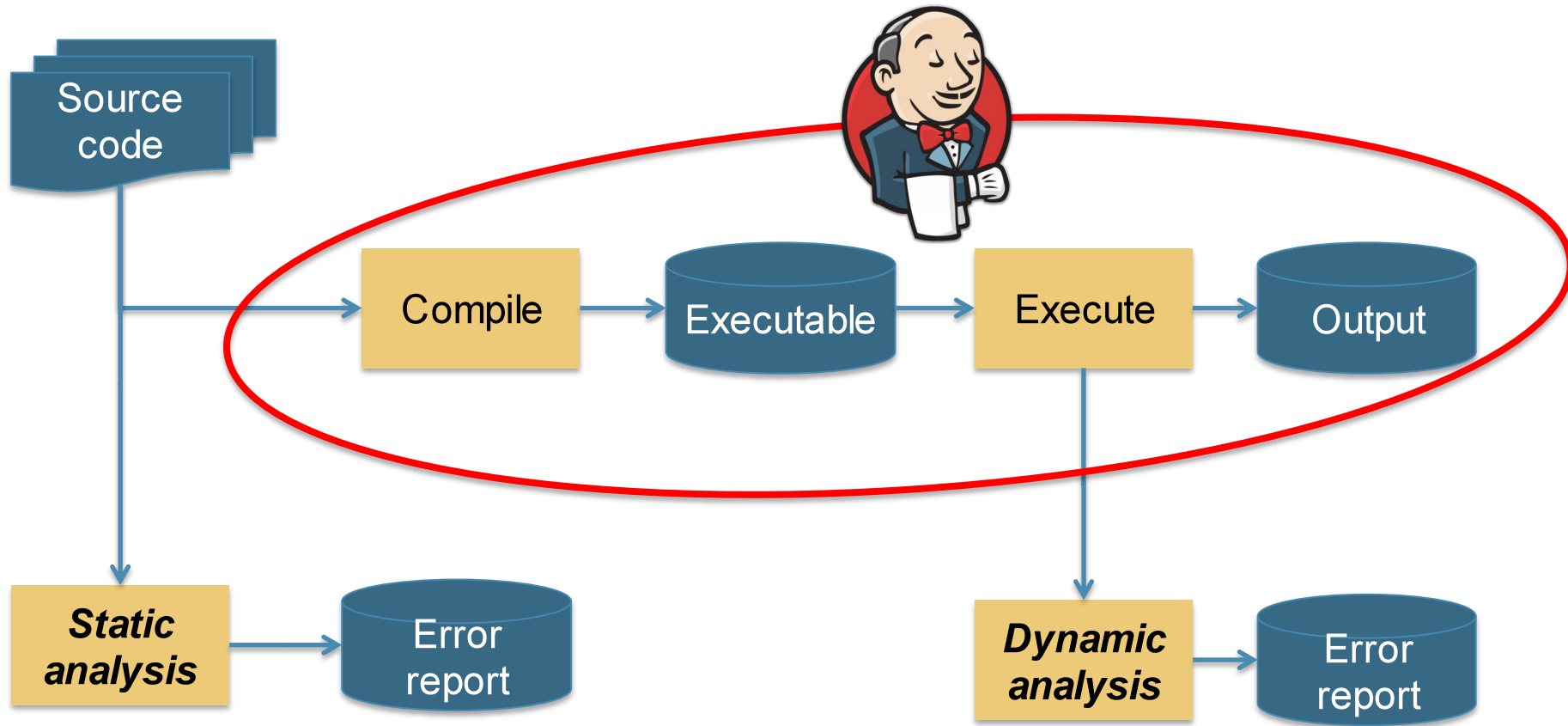
In a bugtracker,
because users found it...

- “ABC doesn’t work”
- “I click on the OK button,
but it’s not OK”
- Of course, users that know how to
write good bug reports DO exist!

**But do you want your users to
find *your* bugs?**



Continuous Integration



Continuous Integration

Continuous Integration tools, like Jenkins:

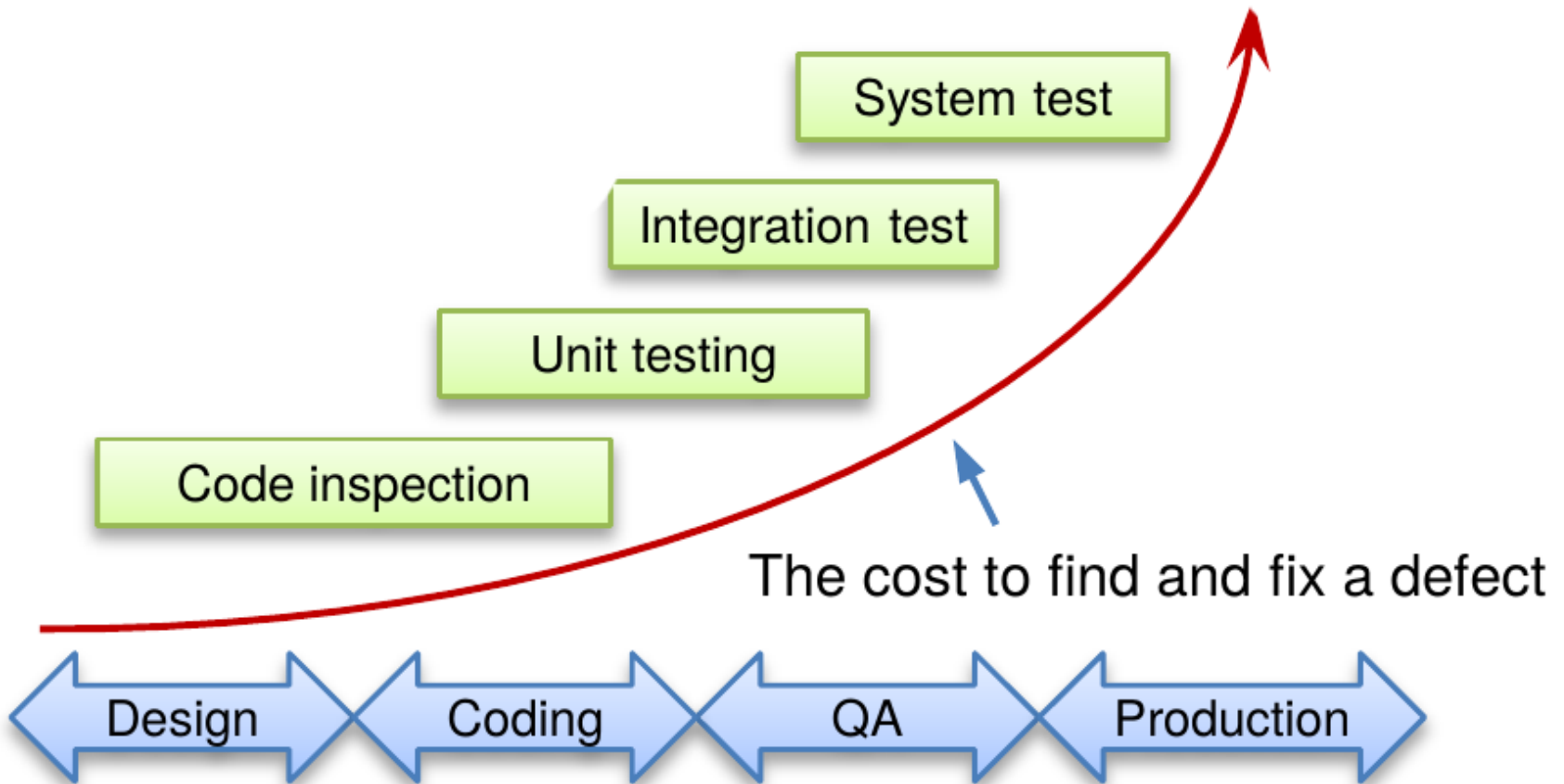


After each check-in or every night:

- Checkout,
- Compile application + tests
- Run all tests
- Scream if tests break (i.e. tests return “fail”)

Sounds like a great opportunity to do dynamic analysis

Cost of a bug (commercial environment)



Find Heisenbugs before they appear

Bugs found when running unit/integration tests with dynamic analysis:

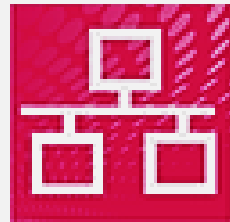
- The night after commit
- Developer still has the code fresh in mind
- Instead of e.g. 4 months later

Current state of open source dynamic analysis tools for use in regression runs:

- **Valgrind/Memcheck/Helgrind:**
 - huge memory overheads on test PC,
 - output interspersed with test output, need to adjust test code
- **Google (T/A/M)SAN:**
 - stop at first error found – no indication how many errors would be found in total run
- If many test binaries need mechanism to merge reports

TCP/IP stack

EXAMPLE



picoTCP

Intelligent
Systems

ALTRAN

SUPPORTING YOUR INTERNET OF THINGS

ABOUT NEWS PROJECTS CONTACT

picoTCP is the answer for a size, speed and feature conscious open source TCP/IP stack for embedded devices.

<https://github.com/tass-belgium/picotcp>

TCP/IP stack on GitHub

17 test/examples/dhcp_client.c

```
@@ -7,7 +7,6 @@
7      7      /** START DHCP Client */
8      8      #ifdef PICO_SUPPORT_DHCP
9      9      static uint8_t dhcpclient_devices = 0;
10     10     -static uint32_t dhcpclient_xid = 0;
...
66     58     void app_dhcp_client(char *arg)
67     59     {
68     60         char *sdev = NULL;
69     61         char *nxt = arg;
70     62         struct pico_device *dev = NULL;
71     63         + uint32_t dhcpclient_xid;
...
91     84         printf("Starting negotiation\n");
92     85
93     86         if (pico_dhcp_initiate_negotiation(dev, &callback_dhcpclient, &dhcpclient_xid) < 0) {
...

```

Patch:

- Global variable moved to stack
- Pointer to stack variable passed to a callback function
- Pointer dereferenced after stack deallocation

The diagram illustrates the changes made in the patch. It shows three key locations in the code: 1. The original global variable declaration: `static uint32_t dhcpclient_xid = 0;` on line 10. 2. The new local variable declaration: `+ uint32_t dhcpclient_xid;` on line 63, which is highlighted in green. 3. The callback function call: `if (pico_dhcp_initiate_negotiation(dev, &callback_dhcpclient, &dhcpclient_xid) < 0) {` on line 93. Dotted blue arrows connect these points: one from the original global variable to the new local variable, and another from the local variable to the address-of operator (&) in the function call. A third arrow points from the function call back to the original global variable location, indicating the dereferencing of the pointer after stack deallocation.



TCP/IP bug fixes on GitHub


 tass-belgium / picotcp

SNTP: Fixed short allocation for server string

When the sntp cookie is created, the server string was being allocated using `strlen()`, which would overflow when a `strcpy` is used from the same source by putting the string terminators out of the allocated object bounds.

Bug discovered by Pareon Verify.

 master  v1.5.1 ... v1.4.2



 danielinux authored on May 21


 tass-belgium / picotcp

IPv4: Check packet len before processing

When a packet is received, the length in the header must be checked against the actual IP buffer length. If the header length has been altered, or it's set to a bigger value on purpose by an attacker, the CRC function may violate the heap memory boundaries.

Discovered using Pareon Verify.

 master  v1.5.1 ... v1.4.2

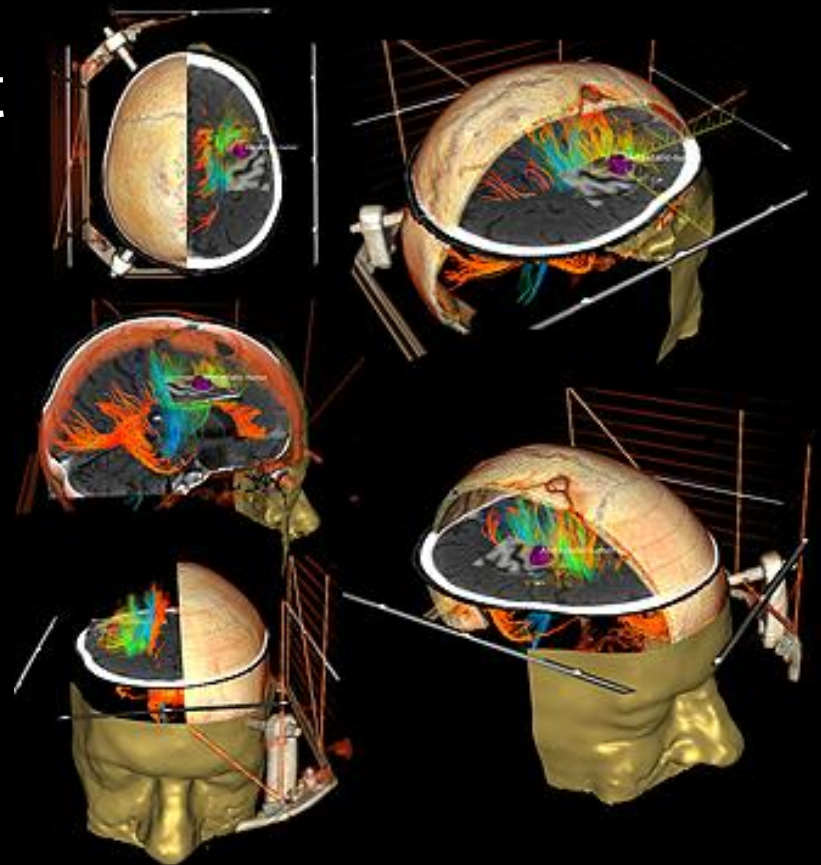
 danielinux authored on May 26

1 parent 2d712fa

“Visualuation ToolKit”

EXAMPLE

- VTK – Visualization ToolKit
- Mature open-source project
- 1.5M lines of C++
- 800K lines of C
- <http://www.vtk.org>



Visualization ToolKit

```
memcpy (cword, "abcdefgh", 8);  
Swap2BRange(cword, 8);  
...  
void Swap2BRange(T* first, size_t num)  
{  
    // Swap one value at a time.  
    T* last = first + num;  
    for(T* p=first; p != last; ++p) {  
        Swap(reinterpret_cast<char*>(p));  
    }  
}
```

T is not char!

- Pointers and casts, C++ templates and classes
- But the code looks OK and...
- Test succeeds

Pareon Verify error message

```
[M0203] Read(s) from uninitialized stack object detected:  
the read in  
  function vtkByteSwapper<2ul>::Swap at vtkByteSwap.cxx:43  
  called from function vtkByteSwapRange<short> at vtkByteSwap.cxx:75  
  called from function vtkByteSwapBERange<short> at vtkByteSwap.cxx:193  
  called from function vtkByteSwap::SwapBERange at vtkByteSwap.cxx:240  
  called from function vtkByteSwap::Swap2BERange at vtkByteSwap.cxx:298  
  called from function TestByteSwap at otherByteSwap.cxx:57  
  called from function otherByteSwap at otherByteSwap.cxx:160  
  called from function main at vtkCommonCoreCxxTests.cxx:372  
performed 1 access of size 1 at an offset of 8 bytes from the start of  
the stack object of size 1024 allocated as `cword' in  
  function TestByteSwap at otherByteSwap.cxx:32  
  called from function otherByteSwap at otherByteSwap.cxx:160  
  called from function main at vtkCommonCoreCxxTests.cxx:372
```

- Easy patch based on the clear error message
- Bug reported in 6.1.0 and fixed in 6.2.0
- <http://www.vtk.org/Bug/view.php?id=14997>

Summary



**Don't Feed the Bugzilla:
Squash (Heisen)bugs Before Release**

Take-away

1. Code is never bug-free,
don't let your users fill up your bug tracker
2. Static errors are relatively easy to catch,
dynamic errors slip through and are found late in release
3. Dynamic Analysis is a “*really good companion*” to static analysis, especially in *Continuous Integration*
4. Serious effort needed to beef up existing open source tools for deployment in CI

Workable commercial tools exist, from Vector Fabrics,
with references from open source

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